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New Limits on Generation-1 Leptoquarks

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New Limits on Generation-1 Leptoquarks

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ABSTRACT

With the turn-on of HERA there is currently considerable interest in the properties of first-generation leptoquarks. In this paper we present new results of a search for these particles at CDF. Our findings are based on an analysis of 4.1 pb^{-1} of data collected at $\sqrt{s} = 1.8$ TeV during the 1988-89 Tevatron run. We assume $\mathcal{O}(\alpha_s^2)$ pair production of fractionally-charged scalar leptoquarks. The leptoquarks are assumed to decay rapidly to first-generation leptons and quarks. We search for an excess of events containing two high energy electrons and two jets and find no events in our signal region. Events outside the signal region are consistent with Z^0+dijet production. Based on this, and assuming $\mathrm{BR}(\mathrm{LQ}_1 \rightarrow e + q) = 100$ %. we exclude first-generation leptoquarks with masses $\mathrm{M}(\mathrm{LQ}_1) < 113$ GeV at the 95% CL. At $\mathrm{BR}(\mathrm{LQ} \rightarrow e + q) = 50$ %, we exclude $\mathrm{M}(\mathrm{LQ}_1) < 82$ GeV.

1. Introduction

We report new results of a search by CDF for generation-1 leptoquarks, LQ_1. We assume $LQ_1\overline{LQ}_1$-pair production via gg fusion and $q\overline{q}$ annihilation. The production rate is $\mathcal{O}(\alpha_s^2)$ and is therefore independent of any new q-l-LQ coupling. Taking $Q(LQ_1) = -1/3e$ leads to the following possible decays

$$LQ_1 \longrightarrow u + e^- \quad (BR \stackrel{\mathrm{def}}{=} x) \qquad LQ_1 \longrightarrow d + \nu_e \quad (BR = 1 - x) \tag{1}$$

We have searched for LQ_1 pairs in two channels. In the case where both leptoquarks decay to ue we expect an e^+e^-+dijet signature with rate $\sim x^2$. In the $(ue)(d\nu_e)$ channel we expect an $e^\pm\nu_e$+dijet signature with rate $\sim 2x(1-x)$. UA2[1] excludes $M_{LQ_1} < 74$ GeV at 95% CL for $x = 100\%$, while searches at LEP[2] find $M_{LQ_1} > 44.2$ GeV independent of x.

2. Electron Data Set

Events in both channels are expected to contain at least one electron and two well separated jets. The channels are distinguished by the presence of either a second electron or missing energy respectively. Since the electron and jet E_T spectra peak at $\sim M_{LQ}/2$ we start with an inclusive electron data set containing well measured isolated electrons with $E_T > 20$ GeV in the region $|\eta| < 1.1$. We have 5007 events, corresponding to 4.1 pb^{-1}. We further require two 20-GeV (15-GeV) jets in the region $|\eta| < 3.5$ for the $e^+e^-(e^\pm\nu_e)$+dijet analysis.

3. e^+e^-+Dijet Channel

In this channel we demand a second well measured isolated electron candidate anywhere in the detector with $E_T > 20$ GeV. To estimate signal acceptance we use the ISAJET[3] MC with HMRS-B[4] structure functions, followed by CDF detector simulation. A background contribution from the double semi-leptonic decay of $b\bar{b}$ pairs is expected to be negligible given the electron and jet E_T cuts. The dominant source of remaining background is the Drell-Yan (γ, Z^0) process with two or more jets coming from initial state radiation. We use the PAPAGENO[5] Monte Carlo to estimate $d\sigma/dM_{ee}$ (Figure 1). Since the dominant contribution comes from Z events we significantly reduce this background by removing events with $75 < m(e^+e^-) < 105$ GeV. This cut is 85% efficient for background while only 8-25% of the signal is lost, depending on M_{LQ}. Integrating the differential cross section $d\sigma/dM_{ee}$ and including cut efficiencies and detector acceptances, we predict the following number of background events

Electron E_T	Jet E_T	Events Observed (Background Predicted)	
(GeV)	(GeV)	Under Z-peak	Outside Z-peak
20	20	3 (4.5)	0 (0.7)
20	15	8 (8.0)	1 (1.2)

Table 1: Observed Events and MC Predictions

The jet-E_T cut is lowered to 15 GeV to check for any signal just below threshold. With no observed events in the signal region outside of the Z-peak we calculate a 95% CL for the signal including statistical and systematic uncertainties. Our measurement of $\sigma \cdot x^2$ is presented in Figure 3. We also show the ISAJET prediction for $x = 100\%$ and using this we find $M_{LQ_1} > 113$ GeV at 95% CL. At $x = 50\%$ the corresponding limit is $M_{LQ_1} > 82$ GeV.

4. $e^{\pm}\nu_e$+Dijet Channel

Instead of a second 20-GeV electron, we now require missing-$E_T > 20$ GeV, and no second electron in the event. QCD and $b\bar{b}$ backgrounds are reduced with an $e\nu_e$ transverse-mass cut $M_T > 20$ GeV, and 15-GeV cuts on the E_T of both jets. Conversion electrons are also removed from our sample. After all cuts we find 115 events. In Fig.2 we show the electron-jet invariant mass for this sample. Leptoquark production would be signalled by a peak above background in this distribution. Also shown is the prediction for 75-GeV leptoquarks assuming $x = 1/2$ and for the VECBOS[6] MC distribution for the dominant W+2jet background.

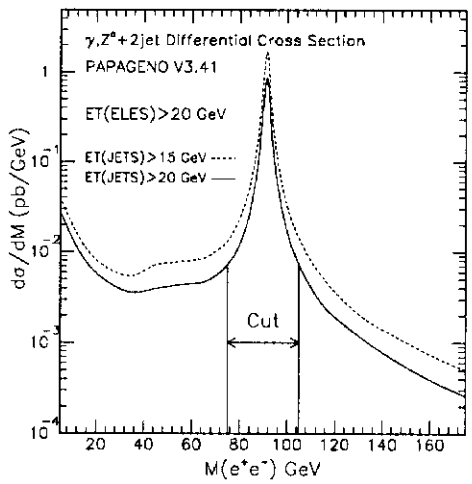

Figure 1: PAPAGENO $d\sigma/dM_{ee}$

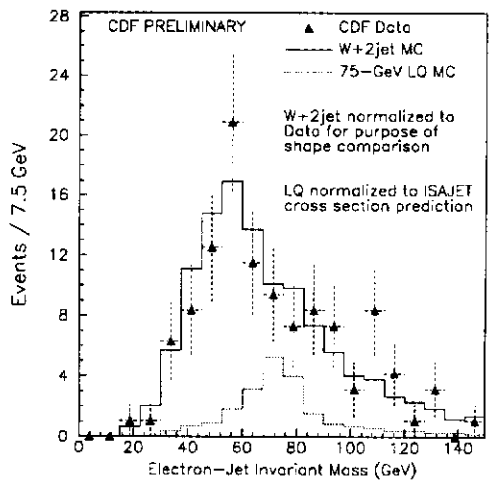

Figure 2: M(Ele-Jet) $e^{\pm}\nu_e$+Dijet Channel

Hard cuts on kinematic quantities such as missing E_T or M_T are insufficient to remove or separate the background. Background subtraction was not attempted due to the large uncertainty on the W+2jet MC cross section. Instead we define a relative likelihood based on 5 kinematic event variables

$$\mathcal{L}_5(M_{LQ}) = \log \prod_{i=1}^{5} \frac{P_{LQ}(v_i)}{P_W(v_i)} \tag{2}$$

The variables used are the electron and leading jet E_T, the dijet and $e\nu_e$ transverse masses, and the missing-E_T significance $E_T/\sqrt{\text{total}E_T}$. The probability distributions $P(v_i)$ are obtained from MC. We find that the distribution in $\mathcal{L}_5$ for the data agrees well with that for a pure sample of MC W+2jet events for all leptoquark masses studied. Signal and control regions are defined as $\mathcal{L}_5 > 2.0$ and $\mathcal{L}_5 < -2.0$ respectively. The signal:background in the control region is $\sim 0.11 - 0.03$ for M_{LQ} in the range 45-75 GeV, while in the signal region the ratio is $4.0 - 0.84$. In the control region the number of predicted W+2jet events is normalized to $N_{\text{OBS}} - N_{\text{LQ}}$(predicted). The number of predicted W+2jet events in the signal region is scaled accordingly. The scale factor ranges from 88% to 109%. 95% confidence levels on a leptoquark signal in the presence of a background are calculated according to the method presented in [7]. Again we include systematic and statistical uncertainties.
In the absence of a signal, and assuming the ISAJET cross section (Fig.3), we derive a 95% CL on M_{LQ} as a function of charged lepton BR x. The results from both channels are shown in Figure 4.

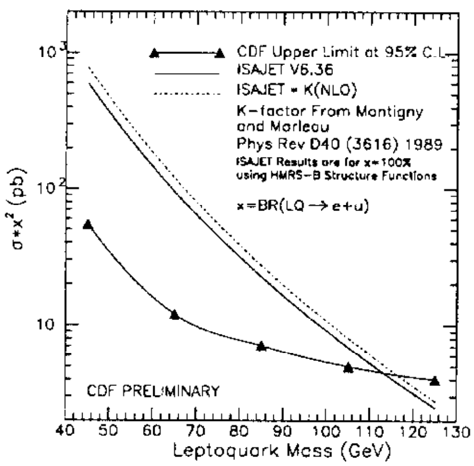

Figure 3: Limits on $\sigma \cdot x^2$ at 95% CL

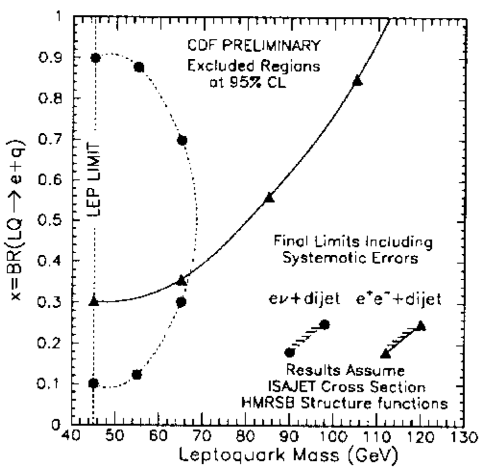

Figure 4: Excluded x vs M_{LQ} at 95% CL

5. References

1. J.Alitti et al. (UA2) *Phys.Lett.* **B274** (1992) 507
2. G.Alexander et al. (OPAL) *Phys.Lett.***B263** (1991) 123
3. F.Paige & S.D.Protopopescu **Brookhaven Report BNL-38034** (1986)
4. P.N.Harriman et al. Phys.Rev.D42 798 (1990)
5. I.Hinchliffe (to be published)
6. F.A. Berends et al. **FERMILAB-Pub-90/213-T** (1990)
7. G.Zech **NIM A277** (1989) 608